The Visual Perception of The Car Drivers Dealing with The Road Supporting Facilities, Road Median, Potholes, and Other Cars on a Freeways With and Without Lighting

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The Visual Perception of The Car Drivers Dealing with The Road Supporting Facilities, Road Median, Potholes, and Other Cars on a Freeways With and Without Lighting

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Abstract. This study evaluated the existing road lighting on Cikampek and Cipularang freeways. Some of the toll roads have no lighting while some do. The toll road has many uphill, downhill and curve or the combination of those. This paper discusses the motorist's perception in the toll road that has lighting and no lighting toward the road supporting facilities, median road, potholes, and other Cars. The results show that motorists have better visual perception in the presence of lighting rather than no lighting condition in recognizing traffic sign and road marking, although there are some insignificant conditions. The presence of lighting also provides a good visual perception to recognize the existence road median, potholes, and other cars. The existing condition of the road lighting on Cikampek Cipularang freeways which does not follow the SNI standard (Indonesia Lighting Standard) are greatly affect the motorist's perception. The existing condition on Cikampek Cipularang freeways has the value of Eav between 6-10 Lux, using HPS lamp and LED lamp that use single sided lighting arrangement with each has different mounting height and luminaire arrangement. We conclude that rearrangement is required to obtain a standardized photometric parameter for the Cikampek- Cipularang freeways.

1. Introduction

The safety of the road users in a traffic and their security against criminal action on the road are major issues to be considered. Therefore, more attention should be given to the condition of the roads and their supporting facilities, such as the apropriate signs and road markings, the road shoulder, and the road median with a proper street lighting. The Traffic signs and road markings are part of the road equipment. The Traffic signs serve as warnings, prohibitions, orders, or directions for the motorists. The luminance contrasts of the traffic signs' coating are also need to be taken into account. It is desired

to have a relatively high luminance of the traffic sign, compared to the surrounding background. In other words, high value of luminance contrast might give high quality of visual legibility. Grade of traffic sign material is a diamond grade, high intensity grade, engineering grade, advertising grade and mixture of engineering and advertising grade, with the grade value from 2.33 to 9.00 base on the laboratory measurement [1]. The measurement results clearly show that the diamond grade material had the highest luminance contrast (grade 9.00), while the advertising grade had the lowest one (grade 2.33). According to the American Association of State Highway and Transportation Officials (AASHTO) M.268-77 standard, which is adapted by The Indonesian Department of Transportation, material for traffic signs should at least be made of engineering grade coating [2]. The road markings serve as an alert, or guidance for the road users in a traffic. The markings on the road marks are longitudinal, cross-road markings, oblique markers, sentence markes or symbol markers. The road markings should be in contrast with the road surface and should be simple. The colors that is widely used for the road markings are white, red, and yellow. The road shoulder is a part of the road that is used for an emergency stop or can also be used as a particular lane for the emergency vehicles, such as the ambulances and fire trucks. The road median on a freeway mostly constructed from a concrete known as Median Concrete Barrier (MCB) and used the plants as an alternative structure. There are two types of MCB, standard type with high 32 "(81.28 cm) and high type 42" (106.68 cm) [3]. The function of the road median is not only as a separator between the paths but also as a safety barrier and retarder of a glare.

The Road lighting is very important for car the drivers especially to avoid the accidents, reduce the criminal activities, and provide the lighting that imitate the daily like lighting. In addition, the road lighting is also a tool for navigating the road users in the night travelling. Road lighting should provide visual performance and visual comfort and help to keep the alertness of the motorist [4]. The road lighting reduces the number of accident. Based on the studies to 62 road lighting and accident from 15 countries, in can be concluded that the road lighting reduce the number of accident on average of 30%. This included all road, freeways, and intersections and interchanged [5]. A meta-analysis of multiple studies of the effect of road lighting on accidents has led to the conclusion that introducing road lighting to previously unlit roads should lead to a 65 percent reduction in nighttime fatal accidents, a 30 percent reduction in nighttime injury accidents, and a 15 percent reduction in nighttime property damage accidents [6]. According to a data from 2011 - 2015, on the Cipularang freeway, the time of the accident occurred mostly at night between 00.00 - 06.00 [7]. The lighting also assists to monitor the presence of potholes and the nearby cars. “Reference [8] mentioned that a good road lighting is needed to estimate the car speed, monitoring harmful objects beside the car, and keep the distance between the cars”. The majority of traffic accidents in Indonesia are caused by human factors (88%), followed by road and environmental factors (8%), and vehicle factors (3%). Vehicle factors in traffic accidents were mainly due to brake failure, vehicle handling, poor visibility, and broken front or rear axles. Road maintenance is critical to ensure that road quality and road performance are sufficient for motor vehicles. Road and environmental factors that caused traffic accidents were mainly due to road damage and potholes, slippery roads, sharp turns, and inadequate lighting [9].

The research was conducted on Cikampek and Cipularang freeways with the existing lighting condition. The Cipularang freeway is connected directly to Cikampek freeway which is the shortest road from Jakarta to Bandung and vice versa, whiles also the busiest freeway. The freeways have various geometric elements of the road, including uphill slopes, downhill slopes, straight sections and curved sections. A road with such complex geometric elements must consider the visibility of the road users that meet the safety standards [10]. The limitation of visibility may cause an accident. An action to overcome the risk is by installing or improving the road lighting [11].

2. Data Collection of The Visual Perceptron

The study used the questionnaires as a measuring instrument, with the statement as shown in table 1. The data collection was conducted by asking the participants to watch the video footage of the freeway with an uphill and downhill road. The number of participant is 60 persons for Jakarta to Bandung

direction, and 59 participants for Bandung to Jakarta direction. The questionnaire consists of 4 conditions of Jakarta to Bandung direction (JB) and Bandung to Jakarta direction (BJ). The questionnaires were filled in a dark room (without lighting from the lights or the sun) which was intended to simulate the condition in a car at a dark night because it is clearer to watch the video in the dark room. The definitions for freeway road lighting conditions are:

a. Condition 1 and 2 is the uphill and downhill road of a freeway without road lighting which is intended as a freeway without installed road lighting.
b. Condition 3 and 4 is the uphill and downhill of a freeway with a white light road lighting, and the illuminance according to existing condition, warm and white light.

Table 1. Statement/Question Items in The Questionnaire

No.	Statement/Question item	Perceived Rate
1	Visibility colors of traffic signs	1 2 3 4 5
2	Visibility of sign symbol and text	1 2 3 4 5
3	Visibility of road marking	1 2 3 4 5
4	Visibility of road median	1 2 3 4 5
5	Visibility of other cars	1 2 3 4 5
6	Visibility of any potholes	1 2 3 4 5

Note: 1 = very negative, 5 = very positive

3. Data and Result

The data collection for the toll road that has uphill and downhill on the Cikampek and Cipularang toll road includes 4 locations of toll road section in the Jakarta-Bandung (JB) direction and another 4 locations in the Bandung-Jakarta (BJ) direction as shown in table 2. There are two types of lamps installed on the Cikampek and Cipularang toll road. The first one is High Pressure Sodium (HPS) lamp with 150 Watt power and 2000K Correlated Color Temperature (CCT) at the Km 91 section of the toll road. The second one is LED lamp with 50 Watt power and 5000K related Color Temperature (CCT) at the Km 107.00; Km 100.600; and Km 101.500 sections. The HPS lamp has 9 m mounting height with 10 Lux average illuminance, while the LED lamp has 7.5 m mounting height with 6 Lux average illuminance measured with the luxmeter.

The existing condition of the Cikampek and Cipularang toll road is shown in Fig 4. It has a total road width 13.5 m which divided into 3 traffic lane which each width 3.5 m, inner shoulder of 1m in inside and outer shoulder of 2m in outside. Using the Dialux software, this information is simulated to obtain the average illuminance using LED and HPS lamp. The simulation result shows that the LED lamp provides average illuminance of 4.44 Lux as shown in Fig. 5, while the HPS lamp gives average illuminance 9.54 Lux which shown in Fig. 6.

Table 2. Uphill road/downhill road location and existing condition cikampek and cipularang freeways road lighting

Uphill road/ Downhill road, Direction, and Condition	**Location Uphill road/ Downhill road**	**Without or with lighting and Correlated Color Temperature (K)**	**Luminaire arrangements**	**Type lamp, wattage lamp, mounting height, and spacing**	**E_{av} measurement (Lux)**	**E_{av} existing condition simulation (Lux)**
Uphill road JB	Km 101.200	Without	-	-	-	-

Uphill road/ Downhill road, Direction, and Condition	**Location Uphill road/ Downhill road**	**Without or with lighting and Correlated Color Temperature (K)**	**Luminaire arrangements**	**Type lamp, wattage lamp, mounting height, and spacing**	**E_{av} measurement (Lux)**	**E_{av} existing condition simulation (Lux)**
Condition 1		lighting				
Uphill road JB Condition 2	Km 91	With lighting Warm (Tk = 2000K)	Single-sided	HPS 150 W Mounting Height 9 m, with floodlight, spacing 40m.	10	9.54
Downhill road JB Condition 1	Km 85	Without lighting	-	-	-	-
Downhill road JB Condition 2	Km 107.600	With lighting White (Tk = 5000K)	Single-sided	LED 50 W Mounting Height 7,5 m and spacing 30m	6	4.44
Uphill road BJ Condition 1	Km 108.800	Without lighting	-	-	-	-
Uphill road BJ Condition 2	Km 100.600	With lighting White (Tk = 5000K)	Single-sided	LED 50 W Mounting Heigh 7,5 m and spacing 30m	6	4.44
Downhill road BJ Condition 1	Km 118.350	Without lighting	-	-	-	-
Downhill road BJ Condition 2	Km 101.500	With lighting White (Tk = 5000K)	Single-sided	LED 50 W Mounting Height 7,5 m and spacing 30m	6	4.44

Note: JB direction from Jakarta to Bandung and BJ direction from Bandung to Jakarta

Based on the result of the t-test using independent as shown in Table 3, there is no significant difference (with significant level > 0.05) for the questionnaire statement 'the clarity in seeing the color of the sign' between with and without lighting on the uphill section of JB part and the downhill section of BJ. The similar result to the questionnaire statement 'the clarity in seeing the symbols and text on

the signs' on the uphill section of JB and BJ toll section, and on the downhill section of BJ, as well as in the case of the questionnaire statement 'the clarity of the road marks'. Only on the BJ uphill section and JB downhill section a significant difference was obtained for the statement 'the clarity in seeing the road marks' (with significance level <0,05) for the road without lighting and the presence of lighting, which are both seen more clearly when there are street lighting. Although in all the results, the mean score obtained in the presence of with lighting is higher than without lighting. It can be said that the presence of lighting is more helpful in the questionnaire statement 'visibility colors of traffic signs', 'visibility of sign symbols and text', and 'visibility of road marking'. The presence of lighting also helps to provide visibility of road median, in the direction of Jakarta Bandung (JB), shown Fig 1, the mean with lighting is higher than without lighting (3.05> 2.53) and (3.43> 3.25) for uphill road and (3.03> 2.61) and (3.29> 3.20) for downhill road. The mean with lighting is also higher than without lighting in the statement 'visibility of other cars' and for the statement 'visibility of any potholes', as shown in Fig 2, and Fig 3. The results in Table 2 are based on the questionnaire data collection at the real lighting condition of the Cikampek and Cipularang toll road.

Table 3. The Test Results Of Visual Perception Of Car Drivers Dealing With The Road Supporting Facilities

No.	Statement item	Uphill road/ Downhill road and Direction	Without lighting	With lighting	Significant Level	Significant? (Yes/No)
1	Visibility colors of traffic signs	Uphill road JB	2.95	3.12	>0,05	No
		Downhill road JB	3.15	3.67	<0,05	Yes
		Uphill road BJ	2.86	2.90	<0,05	Yes
		Downhill road BJ	3.17	3.29	>0,05	No
2	Visibility of sign symbol and text	Uphill road JB	2.60	2.90	>0,05	No
		Downhill road JB	2.85	3.35	<0,05	Yes
		Uphill road BJ	2.40	2.51	>0,05	No
		Downhill road BJ	2.75	2.98	>0,05	No
3	Visibility of road marking	Uphill road JB	3.12	3.77	>0,05	No
		Downhill road JB	3.31	2.65	<0,05	Yes
		Uphill road BJ	2.78	3.19	<0,05	Yes
		Downhill road BJ	3.47	3.22	>0,05	No

Note: JB direction from Jakarta to Bandung and BJ from Bandung to Jakarta

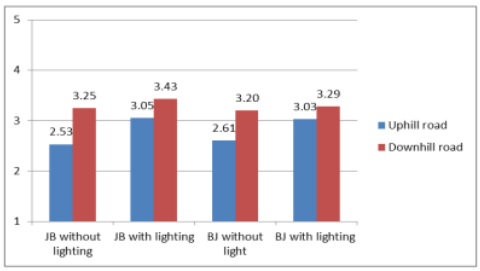


Figure 1. Visual perception of car drivers dealing visibility of road median

Note: JB direction from Jakarta to Bandung and BJ from Bandung to Jakarta
Perceived Rate: 1 = very negative, 5 = very positive

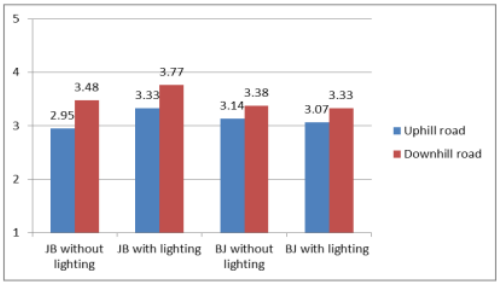


Figure 2. Visual perception of car drivers dealing visibility of other cars

Note: JB direction from Jakarta to Bandung and BJ from Bandung to Jakarta
Perceived Rate: 1 = very negative, 5 = very positive

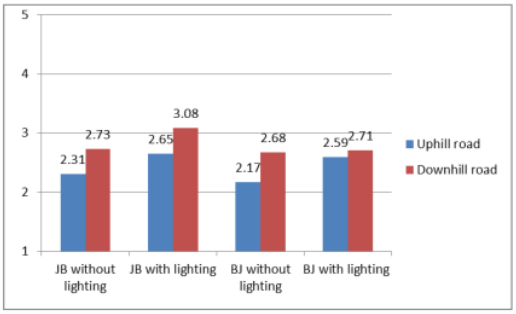


Figure 3. Visual perception of car drivers against dealing visibility of any potholes

Note: JB direction from Jakarta to Bandung and BJ from Bandung to Jakarta
Perceived Rate: 1 = very negative, 5 = very positive

The existing lighting condition of the Cikampek and Cipularang toll road has an average illuminance value between 6-10 Lux which is not in accordance with the recommendation of Indonesian National Standard (SNI). However, this lighting is enough to help motorists to recognize

the signs, markers, road median, and to see the existence of other cars and the pothole in the road, rather than if there is no lighting at all. According to "Reference [12] which regulate the street lighting specification in urban areas that is still valid to date, the average illuminance value E_{av} for freeways is 15 - 20 Lux". In addition, the use of different types of lamp, different CCT, different mounting height, and different wattage lights (shown in Table 2), will make the uniformity and visual performance cannot be achieved. Therefore, the road lighting quality in Cikampek and Cipularang toll needs to be improved which include the lighting level (to achieve average road-surface luminance), overall and longitudinal uniformity, surround ratio, and threshold increment [13]. In addition it is also necessary to determine the luminaires arrangements which is adjusted with the mounting height and effective road width. For this case, when using a single sided arrangement, the minimum height h_{min} is 1 times of the width (w), and minimum spacing S_{min} is 3 - 5 times of the height (h) [4]. Based on the data in Table 2, and Fig 4, with road width 13.5 m, the effective road width w is 11.5 m. For single sided arrangement, minimum height h_{min} is 11.5 m and minimum spacing S_{min} is 34.5 m – 57.5m. It can be obtained from Table 2 that in the Cikampek and Cipularang toll road the minimum height of HPS lamp is 9 m and the LED lamp is 7.5 m, both are not in accordance to the standard. The similar case for the minimum spacing which is also not in accordance to the recommendation. According to "Reference [4], if w<h the lighting arrangement with single-sided should be used", while on Cikampek and Cipularang freeways, the road width is 13.5 m and the mounting height is 7.5 m and 9 m which are not correspond to the "Reference" [4] recommendation because w>h. Therefore, it is necessary to redesign the lighting on Cikampek and Cipularang freeways, and it is recommended to use staggered or opposite type of lighting arrangement. The Cikampek and Cipularang toll road is not in the urban area, which does not always have road lighting. However, according to "Reference [14], article 33 point 3, for the areas that has limited visibility should have street lighting". In the case of Cikampek and Cipularang toll road, there are many uphill, downhill, and curve road. Therefore, it is necessary to provide street lighting.

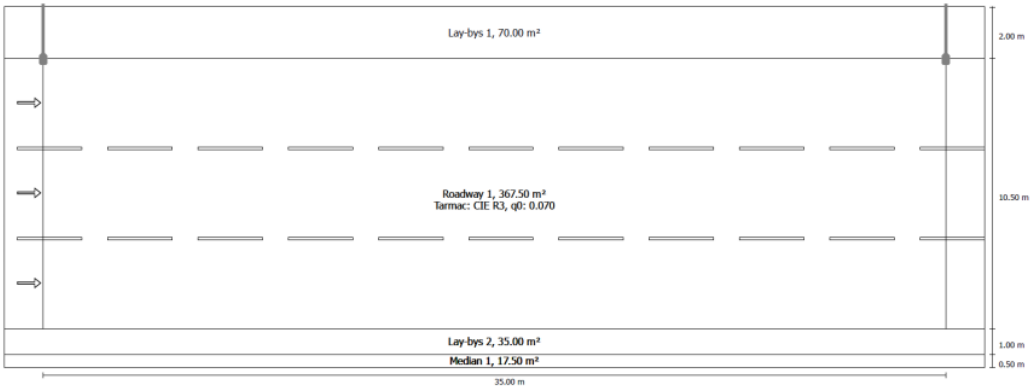
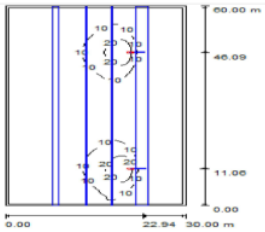


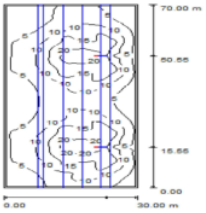
Figure 4. Luminaire arrangement, spacing and road width on Cikampek-Cipularang freeways



Height of Room: 25.000 m, Mounting Height: 8.046 m, Maintenance factor: 0.80 Values in Lux, Scale 1:771

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	4.44	0.42	30	0.094
Floor	20	3.79	0.21	23	0.056
Ceiling	70	0.58	0.40	0.69	0.693
Walls (4)	50	0.76	0.39	19	/

Figure 5. Average Illuminance of simulation result with LED lamp, 50 watt on Cikampek and Cipularang freeways, existing condition



Height of Room: 25.000 m, Mounting Height: 11.420 m, Maintenance factor: 0.80 Values in Lux, Scale 1:899

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	9.54	1.25	22	0.131
Floor	20	7.73	0.59	19	0.076
Ceiling	70	1.63	1.09	1.96	0.671
Walls (4)	50	2.58	0.97	20	/

Figure 6. Average Illuminance of simulation result with HPS lamp, 150 watt on Cikampek and Cipularang freeways, existing condition

4. Conclusion

The motorists have good visual perceptions with the lighting on the Cikampek-Cipularang toll road rather than no lighting in recognizing traffic sign and road marking, although there are some insignificant conditions. The presence of lighting also provides a good visual perception to recognize the road median, potholes, and other cars, although the existing condition of road lighting is imperfect. The existing condition of road lighting on Cikampek and Cipularang toll road is not in accordance with Indonesian standards (SNI) which greatly affects the perception of motorists on the toll road. The existing condition on Cikampek and Cipularang toll road has E_{av} between 6-10 Lux using the HPS lamp and LED lamp with each uses different mounting height and luminaire arrangement, and the type of lighting arrangement is single sided. Furthermore, Cikampek and Cipularang toll roads requires rearrangement to obtain a standardized photometric parameter. In the future rearrangement, the type of lighting arrangement should be replaced with staggered or opposite type. The rearrangement of the lighting on the Cikampek and Cipularang toll road will be presented in another paper.

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